The Commissioning Plan for the DUV-FEL 300 MeV Operation

I Introduction

The DUV-FEL at the NSLS is a laser linac facility dedicated to the linac based light source R&D and applications. It was commissioned in early 2000 for electron beam energy operating below 230 MeV. It was granted routine operation after the extensive ARR review on March 9, 2004 by the DOE.

The DUV-FEL linac was successfully commissioned up to 210 MeV in 2001. Shortly after that, both the HGHG FEL and first user experiment were commissioned. The HGHG successfully lased at 266 nm with 800 nm laser seeding in late October 2002 (L.H. Yu *et al*, PRL ***91***, No. 7, 074801-1 [2003]), and experiments were carried out at the DUV-FEL to further characterize the properties of the HGHG FEL and to demonstrate its stability and controllability. The narrower spectrum and better stability of the HGHG, compared to a self amplified spontaneous emission (SASE) FEL, were observed. Both the second and third harmonic HGHG FEL beams were experimentally characterized using a vacuum monochromator. The pulse energy for both harmonics (133 and 89 nm, respectively) was measured to be about 1 μJ, which is about one percent of the fundamental value at 266 nm.

This first chemical science experiment – on ion pair imaging – used the HGHG's third harmonic beam (89 nm) to study the super excited states of methyl fluoride, a highly flammable gas. Velocity-mapped ion images of the fluoride ion, obtained using intense, coherent, sub-picosecond pulses of 86-89 nm light, revealed a low translational energy, implying a very high internal excitation in the molecule's methyl cation cofragment (W. Li *et al*, PRL **92**, No. 8, 083002-1 [2004]).

In response to the requests of many users to study chemical science at the facility, the NSLS undertook the DUV-FEL electron beam energy upgrade. The linac was upgraded from 200 to 300 MeV to enable the HGHG FEL to produce 100 μJ pulses of 100 nm light. This will help establish the DUV FEL as a premier user facility for ultraviolet radiation, and will enable state-of-the-art gas phase photochemistry research.

The upgraded HGHG will operate at the 4th harmonic with the seed laser at 400nm. The increase of the electron beam energy will be accomplished by installing a 5th linac cavity and two 45 MW klystrons. New modulator and dispersion sections vacuum chambers have been manufactured to accommodate new matching optics and 8th harmonic HGHG.

The proposed commissioning plan covers the newly upgraded DUV-FEL operating at 300 MeV.

II Scope

Fig.1 is the DUV-FEL layout after the 300 MeV upgrade. Three new components, two klystrons and a 3-meter long linac cavity, which are the focus of this commissioning plan, are identified in fig.1. Due to the failure of one of the klystron tubes before the shutdown, klystron D is not connected to the linac system. Fig.2 is the schematic of the DUV-FEL klystrons and linac as installed.

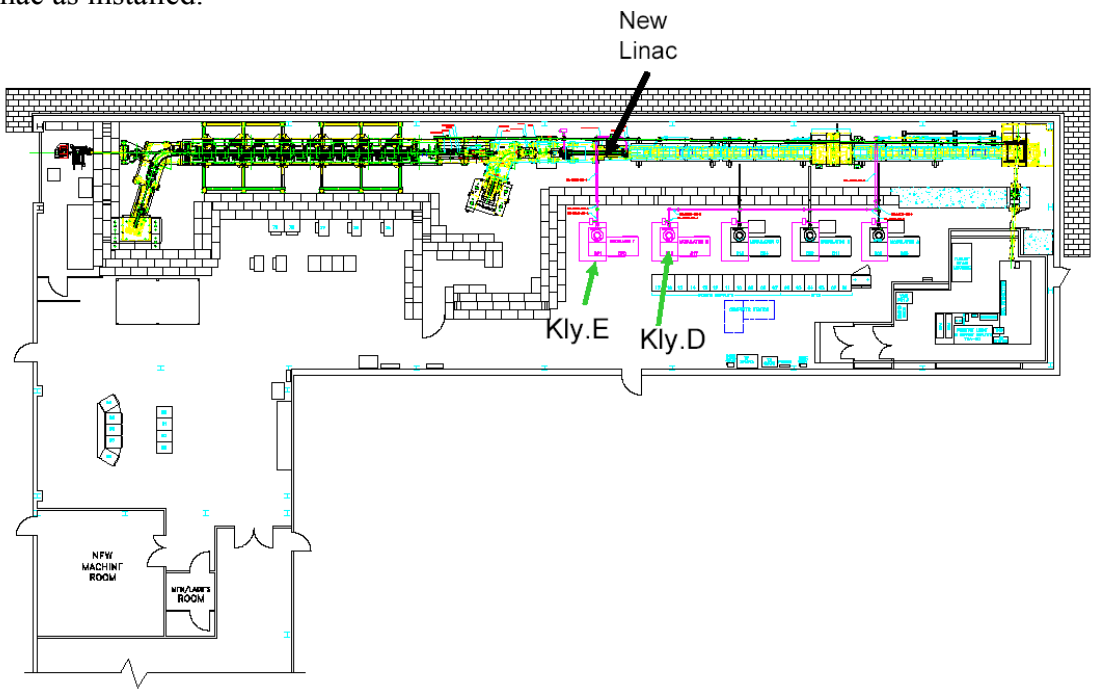


Fig. 1: The DUV-FEL layout.

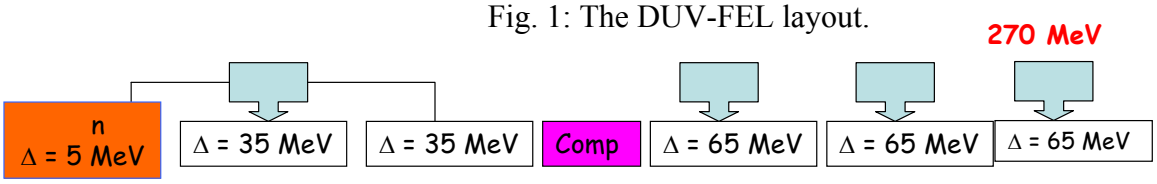


Fig. 2: The schematic of the DUV-FEL RF system.

Other major upgrades are laser and radiation interlocks to incorporate the new hardware. The linac tunnel and end-station are now laser interlockable to accommodate the class IIIB or IV laser light from the HGHG seed laser and FEL output.

The safety analysis and shielding design for the DUV-FEL were implemented for 300 MeV from the very beginning; there is no shielding modification except for two penetrations of the lead shielding for the waveguide. The procedures related to the interlock and new hardware are being updated:
(http://www.nsls.bnl.gov/organization/Accelerator/duvfel/documents/procedures/).

All training requirements for 230 MeV operations are still valid for 300 MeV operation.

The DUV-FEL electron beam energy upgrade project and klystron modulator design have successfully passed two NSLS reviews:

1. Integrated Project Review (Chaired by E. Johnson): this review examined electron beam energy upgrade project overall planning, coordination, ES&H issues and implementation. The final report can be obtained from NSLS Quality Control Coordinator (Rep. No.: 000306).
2. The DUV-FEL Modulator Upgrade (Chaired by R. Biscardi): detailed engineering design and ES&H issues related to the two new klystron modulators were carefully reviewed by this committee. It also addressed any potential hazard for the three old klystron modulators. All suggestions from this review have been implemented (Rep. NO.000327).

The DUV-FEL Safety Assessment Document (SAD) Rev. F and Accelerator Safety Envelope (ASE) Rev. B are the revised versions reflecting the new operating conditions. Both SAD and ASE were reviewed by the BNL ES&H Committee on Oct.1, 2004. Approval was recommended.

The commissioning of the 300 MeV electron beam energy upgrade will proceed according to the following schedule:

1. **Commissioning: (Oct. 1, - Nov. 1, 2004):** NSLS approved the DUV-FEL commissioning below 230 MeV on September 15, 2004 (http://www.nsls.bnl.gov/organization/Accelerator/duvfel/documents/SAD/USI_9-15-04_final.pdf). To insure that the electron beam energy will not exceed 230 MeV during the commissioning and RF conditioning stages, klystron C is locked out with LOTO, tag refers to above Un-reviewed Safety Issue (USI) limitations. All new hardware will be tested during the commissioning stage. The major processes for the commissioning are:

    - Shielding check: radiological shielding, including lead shielding for all klystrons, was checked according to the procedure: http://www.nsls.bnl.gov/organization/Accelerator/duvfel/documents/procedures/LS-SDL-0004.pdf.

- Radiation and laser interlock validation: the both radiological and laser interlock systems were checked before the commissioning according the procedures: http://www.nsls.bnl.gov/ESH/QA/PPS/tests.htm/.

- Modulator testing: the interlock for all modulators (A, B, C, E) were tested according to procedure http://www.nsls.bnl.gov/ESH/QA/PPS/Procedures/LS-PPS-0030_SDL_Modtest.pdf.
- Magnetic field and radiological monitoring: the magnetic field and ionization radiation surrounding the new klystron E will be surveyed by radiological technician during the klystron commissioning, proper signs will be posted according to the survey results.
- RF monitoring: since all high power RF will be confined inside the vacuum waveguide, no RF leak is expected. But RF testing will be done as the klystron is being commissioned.

2. **RF conditioning (Nov. 1 – Nov.10, 2004):** two new klystron tubes (mod. A and E) and the new linac will be conditioned in early November. Radiation and RF monitoring will be done during the RF conditioning. It is expected that the output power for those two new klystrons (A and E) will exceed 30 MW after the RF conditioning.

3. **Electron beam commissioning and fault studies (Nov. 10 – 20, 2004):** after successful completion of the RF conditioning, electron beam will be commissioned up to 230 MeV. Fault studies will be performed to verify the integrity of the radiation shielding after the upgrade. The electron beam operation will follow the procedure - http://www.nsls.bnl.gov/facility/Accelerator/duvfel/documents/procedures/0036/0036.pdf.

4. **HGHG commissioning (Nov. 20 – Dec. 10**): HGHG operating at 200 and 266 nm will be commissioned with electron beam energy below 230 MeV.

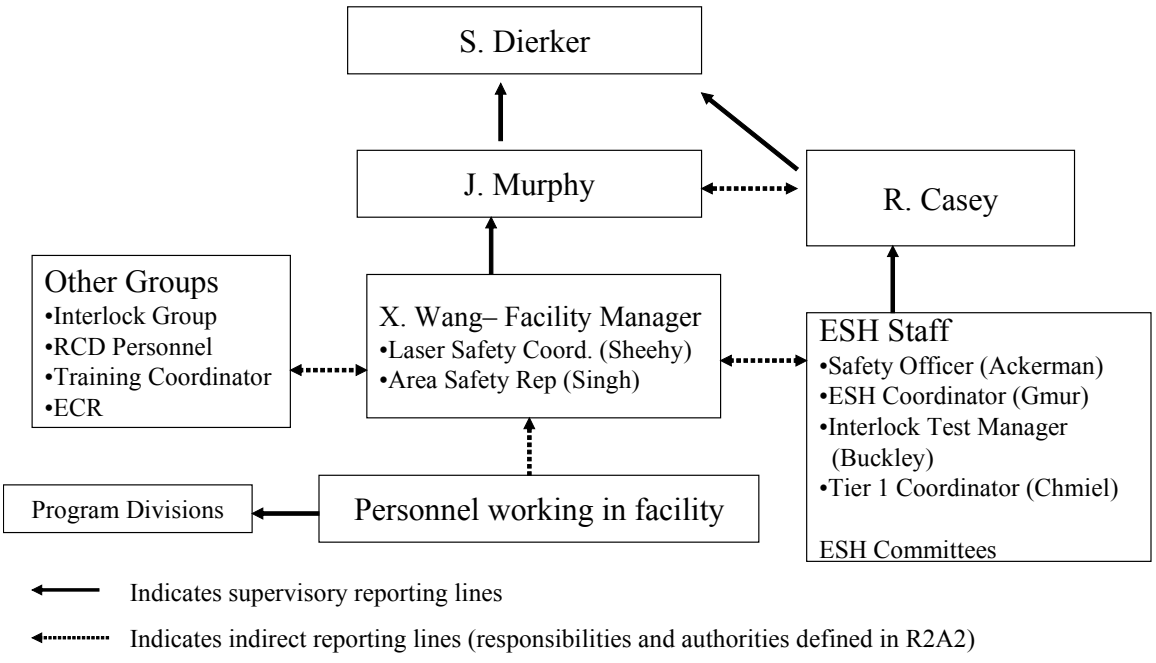
5. **300 MeV commissioning**: Conditional on the approval of the 300 MeV commissioning and operation by the BNL ARR committee and DOE, 300 MeV commissioning can start after the RF conditioning. The main activities for the 300 MeV commissioning will be radiation fault studies and electron beam energy characterization. The electron beam operation will follow the procedure - http://www.nsls.bnl.gov/facility/Accelerator/duvfel/documents/procedures/0036/0036.pdf.

III Relevant Documents

All documentation related the DUV-FEL operation and training can found at the DUV-FEL web site http://www.nsls.bnl.gov/organization/Accelerator/DUVFEL/.

1. Safety Assessment Document: http://www.nsls.bnl.gov/facility/Accelerator/DUVFEL/ under the heading of documents. *Note: the newest revision will not be available until BNL approval is given.*
2. Accelerator Safety Envelope: http://www.nsls.bnl.gov/facility/Accelerator/DUVFEL/ under the heading of documents. *Note: the newest revision will not be available until BNL and DOE approvals are given.*
3. The DUV-FEL Conduct of Operations: http://www.nsls.bnl.gov/facility/Accelerator/duvfel/documents/conduct/
4. The DUV-FEL Operations Procedures: http://www.nsls.bnl.gov/facility/Accelerator/DUVFEL/ under the heading of "Documents".
5. The DUV-FEL Training Requirements: http://www.nsls.bnl.gov/facility/Accelerator/duvfel/documents/training.htm
6. Unreviewed Safety Issues: To facilitate the DUV-FEL new hardware commissioning, the upgraded DUV-FEL will operate under the old SAD (<230 MeV). This issue is addressed as Unreviewed Safety Issues (USI). http://www.nsls.bnl.gov/facility/Accelerator/duvfel/documents/SAD/USI_9-15-04_final.pdf .

IV Conduct of Operations



The above flow charter represents the safety chain of commander for the DUV-FEL facility. The technical responsibilities are summarized in the following:

1. Xijie Wang: the facility manager, responsible for the DUV-FEL operation and schedule.
2. Brain Sheehy: laser physicist, responsible for the DUV-FEL laser system operation and training.
3. Jim Rose: RF engineer, Xijie's back up, and responsible for RF and electrical system.
4. John Skaritka: mechanical engineer, responsible for the DUV-FEL beam line construction and improvement.
5. Boyzie Singh: The DUV-FEL job coordinator.

Other details on the DUV-FEL Conduct of Operations can be located at http://www.nsls.bnl.gov/facility/Accelerator/duvfel/documents/conduct/.

V Training

The training requirements for personnel at the DUV-FEL are classified into three categories:

1. **Visitor:** Visitors will be escorted at all times by personnel who have the DUV-FEL Facility Specific Safety Orientation training.
2. **Facility Specific Safety Orientation only**: all personnel who are not involved in the DUV-FEL operation and user program need the DUV-FEL Facility Specific Safety Orientation training only.
3. **The DUV-FEL operators and users:** The training requirements for the DUV-FEL operators and users are listed in the BeamLine Operations and Safety Awareness (BLOSA) Checklist.

VI Contingency Procedures

To insure the DUV-FEL operation does not violate the ASE, the procedure Temporary Restrictions to DUV FEL Operating Envelope was developed.
http://www.nsls.bnl.gov/facility/Accelerator/duvfel/documents/procedures/LS-SDL-0034.pdf

Revision Log Table

Revision Number	Date Approved	Pages Affected	Description of Revision
A	4/26/02		original
Revision Number	Date Approved	Pages Affected	Description of Revision
B	10/20/04	all	This plan now covered 300 MeV upgrade